ARTICLE X.

ON FUCOIDES IN THE COAL FORMATIONS.*—[WITH A PLATE.]

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§1. DISCOVERY OF FUCOIDES IN THE COAL MEASURES OF SCIENTIFIC IMPORTANCE.

THE scarcity of Fucoidal remains in the strata of the true Coal Measures is so remarkable that it is questionable whether any species of true marine Algæ has heretofore been described from these formations. Up to 1836 one specimen of Fucoides only is mentioned in Thompson's Outlines of Mineralogy, Geology, and Mineral Analysis, at the end of a catalogue of fossil plants of the Coal Measures, containing 290 species, under 37 genera.† Since that time, none of the palæontologists who have enumerated or described coal plants, have noticed a single species of Fucoides from the Carboniferous formations, either of Europe or of America, except the doubtful forms which I have noticed in a former paper.‡ Considered in itself, therefore, the discovery of true Fucoidal remains in strata ascertained to belong to the Coal Measures, is a subject of some scientific interest. This fact, moreover, is intimately connected with the question of the distribution of Fucoidal remains in formations of different ages, and of their value and significance for the identification of the strata where they are found. It bears also upon the problem of the economy of marine Algæ in nature: that is, of the amount and worth of the materials which they have brought and still bring to the economizing forces of this omnipotent treasurer. Viewed under these various aspects, the subject may be considered indeed of some scientific importance.

§2. HABITAT OF THE FUCOIDES HERE EXAMINED.

The habitat or the position occupied by the plants described here, is somewhat peculiar. They were found attached or flattened on the lower surface of a thin stratum of limestone, immediately overlaying a bed of coal six to eighteen inches thick. The Fucoides, for they belong evidently to a kind of marine plants, have thus grown, either as a part of the ma-

* In these remarks, the term *Fucoides* is used in its general sense, as representing remains of evidently marine plants, or Algæ, whose relation to living species is obscure or not yet fully ascertained.

† Quoted by J. P. Lesley, Manual of Coal, p. 219.

‡ Silliman's Journal (2), vol. xxxii, p. 194.

terials of which the coal is a compound, or immediately over them. For they appear to derive the black color, which seemingly paints them on the limestone, rather from the coal than from their own substance. When some detached blocks of the limestone have fallen into the creek, and, washed for a time, have been cleared of the coal which adheres to the lower surface, the matter becomes bleached, and the remains of Fucoides appear in slightly depressed and dark distinct outlines. But when the coal, which adheres to the limestone as if it was strongly glued to it, is removed by mechanical force, the stone preserves its black color, and the remains of these plants are scarcely discernible. On the line of contact with the coal and for one or two inches above it, the limestone, whose thickness varies from twelve to eighteen inches, is somewhat shaly, though of a piece, and homogeneous. It is a kind of black band, containing sulphur and iron in large proportions, and essentially composed of broken remains of innumerable marine shells. Though hard, compact, and in banks generally continuous, it breaks into large cuboidal pieces. The Fucoides, which occupy only a few inches of the lower and shaly part of this limestone, are mixed with the remains of shells, and often perforated and lacerated by them.

§ 3. NAME AND DESCRIPTION OF THE PLANTS.

Caulerpites marginatus, spec. nov., is the name of these Fucoidal remains. Their form, however variable,* may be compared to that of a lyre or harp. From a horizontal base, the margins, at first nearly parallel, slightly diverge in ascending, and then unite into a rounded top, as in fig. 2. Or the outer margin, diverging more in ascending from the base, becomes more extended than the other, and is once or twice broadly lobed or only wavy, as in fig. 3. The fronds vary in length from two inches to one foot, are half as broad as long, and surrounded by an apparently fleshy or tubular margin from one-eighth to one-fourth of an inch broad. Strongly arched ribs, apparently produced by alternate inflation and thinning of substance, pass from the inner side of the rim to the other border, filling the whole lamina. These arched lines look somewhat like the forking or dichotomous thickened veins of some *Cyclopteris* of the coal. But they are not true nerves, for they do not regularly branch or connect with each other. They abruptly vary in thickness or change their general direction, even crossing each other in various ways. This last appearance is likely caused by compression of a body somewhat inflated like a bladder. The ribs, thin and narrow at and near the margin of the frond, are enlarged in the middle. They seem to be produced by such a spongy network of anastomosing filaments, as is seen in some of our living Algæ, which serves especially to strengthen the structure of the plants. The base of the fronds, abruptly and nearly horizontally cut, is joined at one of its corners, generally more acute than the other, to a stalk or stipe, per-

* See plate 1.

haps a primary stem (*surculus*), which is either linear, elongated, apparently tubular, connecting the frond with some point of attachment, or a short, inflated, oval, bladdery tubercle, resembling an organ of suspension in water. These stipes vary in thickness from one-fourth to one-half of an inch, are very abundant on the limestone, much more so than the fronds, appearing like flat cylindrical pipes, mostly simple, curved in many ways, and generally somewhat inflated at one end. I have copied fig. 7 of plate 1, as it is seen on the stone. It seems to represent a branching stipe. But this is probably a deceptive appearance, caused by a casual superposition and compression of three different parts of simple stalks.

§ 4. RELATION OF THESE FUCOIDES TO OTHER SPECIES OF THE PALÆOZOIC AGES.

These Fucoidal remains so remarkably resemble some of those figured by Mr. Vanuxem, in his Geological Report of New York, under the general name of *Fucoides Cauda-galli*, *Fucoides velum*, &c., that their close relation cannot be denied. Specimens of our species, when the rim has been casually destroyed, are exactly like fig. 2, p. 128, of Vanuxem's *Fucoides Cauda-galli*. Indeed, except the border, it would be impossible to point out any character which might serve to specifically distinguish them.

In a re-examination of these fossil plants, the celebrated palæontologist, Prof. James Hall,* considers the circular form of the frond of *Fucoides Cauda-galli* as a result from its development around an ascending spiral axis, the frond expanding more and more in ascending. In consideration of this peculiar mode of growth, the author has grouped the plants of this kind into a new genus, *Spirophyton*, in which he enumerates four species: *S. Cauda-galli*, *S. velum*, both old species of Vanuxem, and *S. typum* and *S. crassum*, two new species.

Though the very clear descriptions and good figures given by Prof. Hall seem indeed to indicate, at least for his new species, the growth of a frond around a spiral axis, it is plain also that we cannot suppose for the plant here above described a similar mode of development. The same can be said, I think, of both the forms represented in Prof. Hall's report, the one p. 80, fig. 2, which the author considers as a distorted portion of a last volution of a spiral of *Spirophyton Cauda-galli*; and the other, p. 81, fig. 3, named *S. velum*. For the first of these fronds has, as it has been remarked, exactly the same general form and appearance as the plant represented fig. 2 of our plate, and the other bears at one of its corners the broken remains of what is rightly called a stem by M. Vanuxem, which indicates a mode of growth similar to that of our *Caulerpites marginatus*. Therefore, these closely related three forms should be forcibly ejected from the genus *Spirophyton*, this name being inapplicable to plants whose growth has been as a plain untorted lamina.

The way of reconciling these discrepancies is, I think, to admit that the fronds of this

* Seventh Annual Report of the Regents of the University of New York, Appendix D, pp. 76 to 84.

group may casually, under peculiar circumstances of habitat, have their laminas or fronds contorted or twisted around their axis, which is here merely lateral. This twisting occurs in a remarkable degree in many species of our living Algæ, especially in those of a hard leathery texture. The most common *Fucus vesiculosus*, for example, can be seen around Boston, on grassy meadows submerged at high water, with its fronds so strongly twisted that its length is reduced by one-half, and that it then looks rather like a whorl of leaves surrounding a central axis than like a long flat linear frond, which it is really. If, therefore, fronds, like the one represented p. 80, fig. 2, of Prof. Hall's report, or plate 1, fig. 2, of ours, whose length attains one foot, were twisted around a lateral axis, here the continuation only of the primary stem, which may force the torsion, the figure resulting from a cross-section of any part of the twisted frond, or from its perpendicular compression, would represent a disk just like that of the new species of *Spirophyton.* And the same twisted leaves, if compressed in different ways and at various angles, would of course produce multiple deformations like those remarked in the polymorphous *Fucoides Cauda-galli.* If this supposition is right, and if all the forms under which the Fucoides of this group are seen, may be explained by it, it excludes the necessity of a new genus and prevents the scattering of plants of similar characters into different groups.

§ 5. RELATION OF THESE FUCOIDES TO LIVING ALGÆ.

It is right to remark, nevertheless, that we have now a genus of living Algæ, represented by one known species only, whose growth seems to be somewhat analogous to the spiral development of the *Spirophyton*, as it is described by Prof. Hall. It is the *Thalassiophyllum clathrus*, Post and Rup., growing on the northern shores of the Pacific, in Russian America. According to Mertens, who has described it, the stipe of this plant is very bushy and branching, each branch bearing at its extremity a leaf, which unfolds spirally in such a manner that a spiral border, wound round the stipes, indicates the growth of the frond. This frond presents a large convex bent lamina without nerves, or, to a certain degree, a leaf, of which one-half is wanting, for the stipe may be considered as an eccentric nerve.* Though an analogy of development may, from this description, appear to exist between the fossil and these living Algæ, there is, I think, an evident and great difference. In Spirophyton, as it is described and figured, it is not a kind of border or stalk, which causes by its own twisting the bend of the frond; it is the lamina which unfolds itself in spiral from its point of attachment and expands in ascending. Hence, fronds of this kind can be but simple, while the Northern Algæ of the Pacific are remarkably bushy branching. These, moreover, belong to a class of highly organized Algæ, while in early geological ages and from analogy with what we know of other beings, we can look in the vegetable world for types only of a very simple organization.

* T. H. Harvey's Nereis Boreali Americana, vol. i, p. 97.

This simplicity of structure, with some peculiar characters of the Fucoidal remains under examination, seem to fix their relation with the *Caulerpæ*, a group of Chlorosperm Algæ of our time. "The fronds of these plants consist of prostrate primary stems (*surculi*), rooting from their lower surface and throwing up erect branches or secondary fronds of various shapes. Their substance is horny, membranaceous, destitute of calcareous matter, their structure uncellular, the cell (or frond) continuous, strengthened internally by a spongy network of anastomosing filaments, and filled with a semi-fluid grumous matter."* The primary fronds or stalks of the species of this order are smooth and glossy, a character particularly marked in *Caulerpites marginatus* of ours. For, on the limestone, even when it has not been washed by the water of the creek, these stalks of a dull grayish color are clearly defined, perfectly smooth, even shining or polished. The development of the secondary fronds of the Caulerpæ is multiform in the extreme, as can be expected in a plant which is of the simplest structure and is formed by the continuous development of a single cell, or is, so to say, nothing but a kind of bag of a flexible tissue. In *Caulerpa prolifera*, Lam., the secondary frond expands into a tongue-shaped, flat petioled, leaf-like division, which is itself proliferous from any part of its surface. In other species the secondary fronds are sometimes pinnately branching into elongated bladdery cylindrical appendages, sometimes irregularly divided into ribbon-like branches, without any appearance of order. Even in *Caulerpa clavifera*, Ag., these secondary fronds are more or less densely set all around by scattered club- or top-shaped vesicular branchlets. The only character which renders our fossil plant in some way different from the forms which we are accustomed to find in this group of Algæ, is its eccentrical shape. But it is seen from plate 1, fig. 4, that the secondary frond is not a second frond, implanted on or born from the primary one, but is really a mere continuation by inflation of the stalk. This, expanding like a bladder, is forced upwards, the division of the stalk forming the thickened or smooth border around it. The stalks or surculi, as seen in figs. 5 and 6, are inflated in various ways, and may, even after dilating into laminas, take again their tubular, more simple form, a disposition which is seen also in some species of *Caulerpæ*.

It is in consideration of those natural affinities, that I have placed the new species of Fucoides of the coal in the genus *Caulerpites* of Sternberg; and the same reasons would induce me to admit into it all the related forms described by Prof. Hall under the name of *Spirophyton*, as well as the peculiar *Fucoides Serra* described by Brongniart.† This last, according to the remarks of that celebrated author, was found in the limestone of Transi-

* Nereis Boreali Americana, by T. H. Harvey, vol. iii, p. 12. Most of the remarks concerning the Caulerpæ are taken from this admirable work.

† Vegetaux Fossiles, p. 71, tab. 6, figs. 7 and 8.

tion at Point Levy, near Quebec, Canada. Its likeness to our species is rather in the mode of growth than in the form. It has nevertheless an eccentrical expansion of the secondary frond, from a round, linear, apparently tubular stalk, which is sometimes only a bladdery oval tubercle. The fronds themselves, though narrower, deeply dentate on one side, and without arched ribs, have the same general outline as *Caulerpites marginatus.* Indeed, in comparing the upper part of fig. 7 of Brongniart with fig. 6 of our plate, or fig. 8 of Brongniart with our fig. 2, one can but see that these so nearly allied forms are of a same type, and can but be admitted in the same genus.*

§ 6. GEOLOGICAL HORIZON OF THE LIMESTONE MARKED WITH REMAINS OF CAULERPITES MARGINATUS.

The new species of *Caulerpites* was found on Slippery Rock Creek, opposite Wurtemberg, Lawrence County, Pennsylvania, at the base of a hill about three hundred and fifty feet high, abruptly cut down by the erosion of the creek. The succession of the strata thus open to view is seen in the following order, ascending:

1st. At the low-water level of the river, a bed of soft, black, easily disaggregated shales, intermixed with small oval pebbles of carbonate of iron. At its upper part, the shales pass into a kind of yellowish ball or clay iron ore, their whole thickness varying from five to eight feet here around.†

2d. They are overlaid by a bed of bituminous, hard splint coal, sometimes shaly, five to twelve inches thick, rarely more, covered by the limestone, with Fucoidal remains, as it has been described above. At Wurtemberg this limestone is one foot thick. In ascending the creek to about five miles above this place, it continues in view at the base of the hills wherever they are cut by erosion. It preserves the same horizon, is marked by the same species of plants, and its greatest thickness is not over eighteen inches.

3d. Over the limestone, fifteen feet of soft, grayish shales, without any trace of remains of fossil plants.

4th. A bed of sandstone, five feet thick, passing sometimes to a hard compound of coarse-grained fire-clay, with leaves and stems of Stigmaria.

5th. Two feet fire-clay.

6th. Three feet hard black limestone, of the same appearance and compound as the limestone of the Fucoides, but without remains of plants.

7th. A succession of thick strata of shales, cut by thin beds of Stigmaria fire-clay and shaly sandstone, with streaks of coal. The shales have an average thickness of one

* Prof. Brongniart (loc. cit.) compares his fossil plant to some species of *Amansiæ,* especially to *Amansia semipinnata.* Prof. Unger, in his Genera and Species, places it in the genus *Sphærococcites* of Sternberg.

† At some other places, on Beaver River for example, these shales attain a thickness of twenty feet, being cut or underlaid by one or two beds of coal, as in Kentucky.

hundred and fifty feet, while the intermediate strata do not have altogether a thickness of twenty-five feet. The shales are generally soft, slightly micaceous, and black-spotted by oxide of iron. They contain in places a quantity of branching cylindrical Fucoides, mostly resembling the small variety of what has been called *Palæophycus tubularis* by Prof. J. Hall.*

8th. These shales are still overlaid by a thick bank of hard, gritty, micaceous sandstone, generally conglomerate at its upper part, and capping the hills here around. Its lower part, somewhat shaly, is also marked by abundant Fucoidal prints. I say *prints*, because these Fucoides in the sandstone are not true remains of plants, but only the moulds left by the decay of marine Algæ, whose place has been filled by a softer whitish sand. Accordingly, the original form of the plants are pretty distinctly printed on the stone. The moulds are generally placed horizontally on the stones, but sometimes penetrate them obliquely or even vertically. These Fucoides are somewhat thicker than those of the shales, varying in thickness from one-half to one inch, either simple, like flexuous pipes, or irregularly forking on one side only, or dividing from a central axis, and sending branches in every direction. They have, as much at least as can be seen from these moulds, the same form and size as the large variety of *Palæophycus tubularis*, Hall, as it is represented figs. 1 and 2, quoted above.

Though the shales of this section are mostly soft, grayish, apparently well fitted for the preservation of remains of coal plants, there is not, in the whole, any trace of ferns or of any of the species of land plants generally and commonly found in the Carboniferous measures. At one place only, just below the mill, one mile above Wurtemberg, the bed of coal at the base of the section is divided into two members by a shaly sandstone, which bears the prints of the bark of *Calamites*, *Lepidodendron*, and *Sigillaria*. The upper division of the coal is here still overlaid by the limestone with *Caulerpites marginatus*.

This distribution of strata strikingly resemble what is seen in some part of the Subcarboniferous measures of Kentucky, Illinois, and Arkansas, where the upper and even the second bed of the Archimedes Limestone are underlaid by shaly sandstone, marked with remains of large coal plants, especially trees and thin strata of coal. In the same way the fossil remains covering the soft shales and printed with the upper Conglomerate Sandstone, are like those remarked in the Chemung, along Oil Creek, or in the Waverly Sandstone of Ohio. They appear indeed identical. Relying then on palæontological evidence, I could but consider the hill opposite Wurtemberg as formed mostly of Chemung measures, and the Conglomerate Sandstone of the top as the equivalent of the Millstone grit. It was only after conferring upon the matter with my friend, Prof. J. P. Lesley, than whom no

* Palæontology of New York, vol. i, p. 7, tab. 2, figs. 1, 2, 4, 5.

geologist is better acquainted with the distribution of the measures in the whole extent of Pennsylvania, that considering the anomaly of the presence of the Chemung in that part of the State, I began a stratigraphical survey of that country, disregarding every kind of palæontological evidence.

Beginning at Homewood Station in Beaver County, the Millstone grit is there exposed along Beaver River with a thickness of one hundred and sixty feet, its base resting on a bed of ball and clay iron ore, soft black shales, with pebbles of carbonate of iron, thin layers of coal, &c. Higher up, at Homewood Furnace, and at the mouth of Coneconessing Creek, the Millstone grit is still one hundred and ten feet thick, and is underlaid by the same kind of shales and ball iron ore. Up the Coneconessing the stream flows between banks of the Millstone grit, which slowly decreases in thickness. At the mouth of Smalley's Run, six miles above, these measures are only sixty feet thick, and the Subcarboniferous strata exposed there show the same nature and distribution as at Homewood Station. The thinning continues at about the same rate to the mouth of Slippery Rock Creek, where banks of hard Conglomerate, forty feet thick, descend to nearly the level of the river. Six to eight feet of Subcarboniferous measures are exposed here at low water. From here, in ascending Slippery Rock Creek, the decrease in the thickness of the Millstone grit becomes more rapid and irregular; these strata changing here and there into shaly sandstone, five to six feet thick, then disappearing entirely, to be seen in place again a little higher up in the creek. The last appearance of the Millstone grit is just below the lower mill at Wurtemberg, where the sandstone, still hard and gritty, is six feet thick, and the black shales and clay iron ore are exposed under it six to eight feet thick; there it definitely loses itself in a thin bed of soft shaly sandstone, wedging into the top of that clay iron ore which in the section is marked as under the bed of coal. From Wurtemberg these strata, preserving the same character and horizon, continue along the creek, without any trace of sandstone, to six miles above, where the Millstone grit reappears in the same manner and at the same horizon as it is seen passing away at Wurtemberg, and rapidly increasing in thickness. At Seceder's Bridge, nine miles above Wurtemberg, it is already one hundred and ten feet thick, underlaid by forty-nine feet of Subcarboniferous measures.

From these observations it follows:

1st. That the whole thickness of the strata marked in the section of the hill opposite Wurtemberg, including the lower bed of coal and the limestone with Fucoidal remains (*Caulerpites marginatus*), belongs to the Carboniferous formations.

2d. That, from Homewood Station to Seceder's Bridge, a distance which, in a straight line, is not more than fifteen miles, there is in the Millstone grit formation a wide, nearly abrupt gap, about five miles broad, where the Carboniferous measures, immediately overlaying the shales of the Subcarboniferous, are mostly marked with remains of marine

plants of the same type, if not of the same kind, as those which we generally consider as characterizing the Chemung group.

§7. GENERAL DISTRIBUTION OF SOME SPECIES OF FUCOIDES IN THE PALÆOZOIC AGES AND THEIR VALUE AS CHARACTERS OF SYNCHRONISM.

The moulds of Fucoidal plants, observed in abundance at the base of the gritty sandstone which caps the hills at and around Wurtemberg, about the height of three hundred feet in the Coal Measures, represent a species apparently identical with, or at least undistinguishable from the large variety of *Palæophycus tubularis*, Hall. The Fucoides in the shales, inferior to this sandstone, resemble the small forms of the same species and *Palæophycus irregularis*, Hall, which Prof. Göppert considers as a mere variety of it. Now, the remains of marine plants of this kind already appear in the Lower Silurian Calciferous sandstone, and may be considered as representing some of the primordial types of the vegetable world. The polymorphous *Fucoides antiquus* of the authors (*Buthopteris antiquata*, *B. gracilis*, *B. palmata*, *B. impudica*, *B. ramosa*, Hall) is common in strata of the Upper Silurian Clinton group; is especially abundant in the Chemung of Pennsylvania and Ohio, and reappears in the Cretaceous formations of Europe. At least *Fucoides Targioni*, Brgt., of this epoch, so well resembles in its multiple varieties the different forms of *F. antiquus*, that it cannot be separated by appreciable characters.* The group of Fucoides, which we have examined in this paper, has representative fossil remains, apparently identical in species, in the whole extent of the Devonian Measures. At least the same form of *Fucoides Cauda-galli* of the Corniferous period is seen in the Chemung or Waverly sandstone of Ohio, and is especially abundant in strata scarcely fifty feet lower than the base of the Millstone grit of Southeast Kentucky. It may be that the fossil remains represent different species, for even *Caulerpites marginatus*, which ascends into the Coal Measures, is, when its border is casually destroyed, undistinguishable from *Fucoides Cauda-galli*.* But we are authorized from these facts and others of the same kind to conclude that most of the marine Algæ, of which remains are found in the Palæozoic strata, have had a wide range of distribution. From this, it is contended, perhaps rightly, that they cannot be considered as reliable guides in the determination of geological horizons.

If this discredit was limited to the remains of marine Algæ only, it would perhaps not be worth considering in any way. But it touches, by inference, every kind of fossil plants, and thus tends to eliminate as useless some palæontological data which are certainly of practical importance. I allude to the remains of land plants, especially the coal plants, some of which may be justly considered as characteristic even of the horizons of the various beds of coal.

* Geological Report of Pennsylvania, p. 848. Göppert, Fossil Flora des Silurischen, p. 434.

We know little indeed of the true forms and nature of fossil Hydrophites. Mere cellular plants as they were, nothing of them has been preserved by fossilization but some moulds or indistinct impressions; hence the impossibility of discovering peculiar forms of organism, which might be used as reliable specific characters. In looking over the innumerable remains of Fucoides, which cover some strata of the Chemung of Pennsylvania or of the Waverly sandstone of Ohio, for example, we perceive at first such differences in the shape of these fossils that their separation into groups appears an easy task. But in time, when these remains are more thoroughly studied, the gaps are filled by so many intermediate forms that the whole fields of this vegetation of old appears like a grass-plot, each blade of which has some peculiar feature, but none marked enough to make it positively distinct. Therefore we are led to admit, either that there are nearly as many species as individuals, or only one species, represented by a great number of closely allied varieties. Of course the impossibility of separating these fossil remains into well-characterized groups renders them unavailable as geological guides.

This difficulty is not met with in the study of the fossil coal plants. For, like the acrogenous vegetables of our time, a class to which they mostly belong, they have woody tissue and vessels as constituents of their stems and foliage, and thus generally preserve their essential forms, in the process of mineralization, at least under certain circumstances. The leaves are not only well defined in outline, but their surface is generally marked by a distinct system of nervation, peculiar to most of the species. Some of these may be followed and studied in the development of leaves, branches, trunks, and even fruits, the trunks being recognizable by peculiar cicatrices on the bark, and the fructifications being sometimes found attached to the plants to which they belong. Hence, if the generic and specific characters of these plants cannot be established on a true scientific basis, they are nevertheless evident enough to allow an identification of the remains found in connection with the beds of coal, and thus to permit a reliable comparison in their distribution, or to fix the peculiar horizon where groups of these plants may belong.

On the other hand, marine plants, like every other kind of vegetable, are apt to modify their shape or to vary according to influences affecting the medium in which they live. In the palæozoic times the temperature of the sea was regulated rather by the heat of the earth than by atmospheric action, and thus was scarcely variable. The same forms of life could therefore be preserved in this medium for a great length of time,—longer indeed in the vegetable than in the animal world,—for the life of plants is not in water exposed to destructive accidents, like that of animals. And in its proceeding and re-

* Prof. James Hall, with remarkable foresight, obtained through his intimate acquaintance with the distribution of the Palæozoic fossils, remarks in his report (loc. cit. p. 83) that species of Fucoides of the group of the *Cauda-galli* might perhaps be found in the Lower Coal Measures of Pennsylvania.

ceding periods the sea brings with it and disseminates the seeds and branches of its Hydrophites, which germinate again, reproducing identical forms wherever circumstances are favorable to their development. But that terrestrial plants, like those of which the coal is a compound, should have been exposed to some modification of life after each of those revolutions, which so often totally changed the surface of the land during the Carboniferous epoch, is an assertion which can only be considered reasonable. For each of these revolutions may have influenced the atmosphere, either in its degree of density or of humidity, or in its chemical compounds. Moreover, each of them at least has evidently modified the land-stations inhabited by the plants, either by leaving the surface more or less penetrated with humidity, or by covering it with deposits of another nature, or with other elements of vegetation, sand, lime, mud, &c.

This assertion does not force us to the conclusion that all the plants of the Coal Measures have been totally destroyed after each submersion of the land, and been replaced by other species; but only that some of the predominant species have lost in the number of their representatives; that a few have disappeared, while new kinds have taken their place; and that accordingly, for any particular horizon, the group of vegetation has a character which may be recognized in its fossil remains, and serve as a true and reliable guide for the identification of the coal strata.

This is not said as a reaffirmation of a personal opinion expressed elsewhere.* For, with a few exceptions, all the authors who have studied the fossil plants of the coal, in relation to their habitat, have come to the same conclusion. Prof. Brongniart's remarks on this subject are worth recording. He says:† "But if the vegetation of our earth has been maintained without great changes during this whole period of time (the Carboniferous epoch), it is not the less certain that very marked changes in the species may be observed during the deposition of the various strata. Thus, in one and the same coal basin, each bed has characteristic species which are not found in more ancient or more recent strata, and which the miners themselves recognize as peculiar to a coal bed." Another celebrated European palæontologist and botanist, Prof. W. P. Schimper, of Strasbourg, records the same fact in a recent work, saying‡ that in the same coal basin a variation of species is observable in passing from the inferior to the superior strata. So remarkable is this change that the highest strata of the true Coal Measures are marked already by species which, like *Pterophyllum*, are characteristic of the Trias, or even of the lower Jurassic formations.

Though the researches on the palæontological botany of our American coal fields are only in an incipient state, and thus our acquaintance with the leading species of various

* American Journal of Sciences and Arts (2), vol. 30, p. 367, Geological Reports, &c.

† Tableau des Genres (1849), p. 95.

‡ Terrains de Transition des Vosges, Partie Palæontologique (1862), p. 318.

horizons is very limited, the value of what is known already and applied to the identification of strata is demonstrated and strengthened by every new discovery.

§ 8. DOES PETROLEUM ORIGINATE FROM THE DECOMPOSITION OF MARINE PLANTS?

Considering the question of the origin of our deposits of petroleum, some geologists have expressed the opinion that they might be due to the decomposition of marine plants, as coal is the result of the decomposition of a terrestrial vegetation. This conclusion is but natural, for there exists an evident correlation between the formation of both kinds of deposits of bitumen. But this relation cannot be, or at least has not yet been, established by direct proofs or experiments, and that is probably the cause why the subject has not been studied more in detail.

§ 9. FECUNDITY OF THE MARINE VEGETATION AT THE PALÆOZOIC AGES.

There is no doubt that the marine vegetation of the Palæozoic ages can be compared, for luxuriance, and in some measure for its composition also, to the terrestrial vegetation of the coal epoch. From the Upper Devonian down to the Lower Silurian, some strata of shales are not only covered, but indeed filled, sometimes for hundreds of feet in thickness, with fossilized forms of Hydrophytes. These evidences of a primordial vegetable world are far more numerous than the remains of land plants in the shales of the Coal Measures. Nevertheless, they appear to belong to plants of a soft tissue, mere cellular, probably mostly uncellular vegetables, the debris of which had not by much the same chances of fossilization.

The superabundance of vegetation testified by fossil remains in Palæozoic ages is in accordance with one of nature's most evident laws. The amount of carbonic acid gas is acknowledged to have been, at the Palæozoic times, far greater in the atmosphere, and also in the water of the seas, than it is now. The prodigious luxuriance of the vegetation of the coal period is rightly ascribed to this fact. It cannot be supposed that in the sea the vegetation, which is there also the intermediate agent between animal life and unorganized bodies, gaseous or mineral, should have been in a diminutive state when its action was the most in demand, like its development, for the purification of the water and the transformation of the superfluous carbonic acid gas into organism and oxygen.

We have no proofs from fossil remains that the Hydrophytes of old attained a very large size. The largest circular fronds of *Fucoides Cauda-galli* show a diameter of about one foot; the greatest length of the branching Fucoides in the Chemung is from two to three feet. But we cannot judge all the vegetable representatives of an epoch from a few fossilized specimens. These may have belonged to a species of a more compact organization, or to some kind of Corallines, which had their surface covered with a hard crust of lime, while other groups of a soft, mere cellular tissue, which had representatives of large size, have been totally decomposed and destroyed. There is no need however of this hypothesis, on the size of the Palæozoic Algæ, to argue by comparison on the fecundity of

the marine vegetation of old. Small species of Hydrophytes, in our time, afford sufficient analogies. The great bank of *Sargàssum*, which extends between the 20th and 45th parallel of latitude, covers, according to Humboldt's computation, a space of more than 260,000 square miles. In places this floating bank is so thick as to arrest the progress of vessels, and it appears at present to be of the same extent and to occupy the same place as when it was first noticed by navigators. What can we then infer to have been the result of a vegetation whose force was at least double of what it is now, and which has written its history in whole strata of great thickness?

§ 10. ANALOGY OF LIFE AND FUNCTIONS IN BOTH THE TERRESTRIAL AND THE MARINE VEGETABLE WORLD.

It cannot be presumed that this whole vegetable world of Palæozoic seas has left nothing after it but useless petrified remains. In the march and development of nature's productions, nothing of the materials employed is ever lost. The smallest atom of matter is preserved in some way, if not constantly remodelled. Thus we find the key of a new life, of a new creation, in the remains of a destroyed one. Thus, some leaves, preserved by fossilization, in the shales of the Coal Measures, open to our view not only the whole world of an ancient vegetation, but its predestinated result, coal deposits, slowly laid up by its agency. Thus also the remains of marine plants, in the shales of the Devonian, point out, I think, not only the fecundity of an ancient marine vegetation, but its result in the contemporaneous deposits of petroleum. Indeed, both kinds of vegetation have great analogy of life, if not of organism. The plants of the coal, by their structure, the form of their long pointed leaves or indefinitely divided fronds, were shaped for the absorption and the transformation from the atmosphere of the greatest amount of carbonic acid gas into woody tissue. The Chlorosperm of the Palæozoic times, with their simple bladdery conformation and their green color, were undoubtedly prepared to perform in the water the same functions as the coal plants performed in the atmosphere. As the result of terrestrial vegetation has been, first woody tissue, and then, by its decomposition, coal, so the result of marine vegetation has been, first cellular tissue, filled with a kind of liquid carbon, and as the carbon is unalterable, the decomposition of the plant has left it free as fluid bitumen or petroleum.

§ 11. WHAT CHEMISTRY INDICATES ON THE SUBJECT.

We cannot follow, in our day, by means of the accumulated remains of Hydrophytes, the slow process of carbonization, and compare its results at different stages of its development, as we can by help of the remains of land plants, in the formation of peat bogs, lignites, &c. This only has been observed: When marine vegetables are thrown upon bogs and mixed with terrestrial plants as compound of the peat, they do not leave any trace of organism or primitive form, and the peaty matter, then of a deeper black color, is a softer, more homogeneous compound, richer in bitumen. When, detached by storms or tides, Algæ

are heaped in great masses on sandy shores, they promptly decompose, passing first to a black, soft paste, and then to a glutinous fluid of the same color, which exhales a strong disagreeable odor, and penetrates the sand. Chemistry has not analyzed these matters resulting from the decomposition of Hydrophytes, nor even species of marine Algæ;* and therefore it is not proved that there exists a direct relation between them and petroleum. Chemistry demonstrates, however, that petroleum and coal are both compounds of the same elements; and the former matter being proved of vegetable origin, the second is necessarily, by induction, referred to the same.† And as some substances, like iodine, which was formerly procured from marine plants only, are now more abundantly obtained from petroleum, chemical analyses, I think, confirm in that way the relation between petroleum and Hydrophytes.

Though chemistry is not directly interested in it, it is but right to refer here to a peculiar fact which bears upon the subject. The Algæ, especially the group of the *Caulerpæ*, feed some of the animals of the seas, remarkable for the size and the prodigious fatness of their bodies. The green fat of the turtles, says Harvey,‡ so much prized by aldermanic palates, may possibly be colored by the unctuous green juice of the Caulerpæ, on which they browse. The same could be said of the color of the Devonian petroleum, which is exactly that of the Chlorosperm Hydrophytes. It is not positively ascertained, I believe, if whales and other marine mammifers of this kind, whose bodies are large reservoirs of oily matter, are true Algæ-feeders; but when killed, the stomachs of these animals are always found mostly filled with marine weeds.

§ 12. GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION OF PETROLEUM DEPOSITS AND FUCOIDAL REMAINS.

A last argument, no less conclusive on the subject, is taken from the geological and also from the geographical relation between deposits of petroleum and Fucoidal remains.

Oil-bearing strata are seen in the Coal Measures mostly inferior to the big bed of coal No. 1, which is often a cannel coal; and sometimes also, but rarely, at a higher horizon, as, for example, below coal No. 3, and also coal No. 12, generally in more or less evident connection with cannel coal. This has probably led to the opinion, still admitted by some geologists, that all the deposits of petroleum owe their origin to a slow decomposition of coal, under some peculiar influences. As there has not heretofore been observed any indi-

* Prof. Liebig, to whom I wrote a *résumé* of my opinion on the subject, with the request that he would point out to me the result of chemical analysis of marine plants, if there were any, either in support or discredit of my ideas, kindly answered: "That there were unhappily no analyses of species of Fucus, or of other Hydrophytes, which could be used as affording support to my views. But that my arguments, based on exact researches, were so conclusive, that for himself, at least, they had removed any doubt of the truth of the theory."

† See, on this subject, a very remarkable and most instructive paper, by Sterry Hunt, in the American Journal of Science and Arts (2), pp. 156 to 171.

‡ Loc. cit., vol. i, p. 31.

cations that remains of marine plants might have existed at some places mixed with the aerial plants of the bogs of the coal epoch, it was not easy to account for such a phenomenon as that of the formation of coal and petroleum at the same horizon and under the same circumstances. But this curious fact, I think, is explicable now. When the combustible matter has been formed especially from the remains of aerial plants, whose tissue was mostly vascular, or vascular and cellular, like that of the *Lepidodendron*, *Sigillaria*, ferns, etc., it becomes by mineralization a hard coal, with thin layers or distinct laminas, sometimes shining, sometimes mixed with opaque layers and flakes of charcoal, and giving, by combustion, a proportion of ashes according to the nature of the wood. When it has been formed merely by floating fresh-water vegetables, like *Stigmaria* and its leaves, the compound, originally half fluid and more easily decomposed, becomes, by the slow process of combustion, compact, homogeneous, without apparent layers, tending to mere bitumen, thus forming the different varieties of cannel coal. Now, I believe that when this floating vegetation has been more or less densely intermixed with marine plants, and perhaps also influenced by marine water, the almost total absence of woody fibres has casually prevented the bedding of the material, and so, by slow maceration, part of it has been transformed into fluid bitumen. It is probably for this reason that we see, sometimes, as at Breckenridge, in Kentucky, a bed of cannel coal so nearly decomposed into petroleum that it can scarcely be used as coal, and at a lower level, even in close proximity, and where every trace of coal has disappeared, inferior strata of sandstone, strongly impregnated with petroleum.

In descending from the base of the Coal Measures into the Devonian, we find deposits of oil nearly in the whole thickness of this formation, with the exception of the old red sandstone, equivalent of the Ponent and part of the Vespertine of Pennsylvania. All the plants of this formation, and they are numerous enough, belong to swamp or land plants, and no trace of petroleum has been seen in these measures. But down from this red sandstone, the Chemung is full of remains of Fucoides, and where they are found all the sandstone strata of this formation are more or less impregnated with oil.

Still lower the black shales of the Hamilton group are so much charged with bitumen that they have often been considered as the true source of the Devonian petroleum. There the remains are nearly, almost totally, obliterated. A few teeth of fishes and small shells, very rarely large trunks of *Lepidodendron*, nothing more, at least in those extensive deposits, generally of great thickness, which border our Western coal basins. The color of these shales, and the bitumen which they contain, indicate a formation under water, under the influence of a powerful vegetation; and a marine vegetation, without doubt; else, besides the well-preserved trunks of *Lepidodendron*, which have probably been brought floating, we should find there other remains of aerial plants. At Worthington, in Ohio,

where I have spent much time in searching for fossil remains in these black shales, I have seen them often covered with round spots of coaly matter, varying in diameter from half an inch to one foot, showing no trace of organism, and resembling some kind of round, hard Ulvaceæ, like those which are seen in great quantity attached to the muddy shores in shallow water.

Descending further down in the Lower Devonian and Upper Silurian, we see there also the rocks saturated with petroleum, and generally marked by an abundance of Fucoidal remains. It is probably from the rocks of the Upper Silurian that Prof. Brogniart obtained his Fucoides from Canada. In Ohio and other Western States, where the Upper Silurian limestone is barren of remains, it does not show any deposits of petroleum. In Canada the same rocks have both Fucoides and fluid bitumen. Prof. Lesley, after an examination of the east end of Canada, Gaspé, wrote me (5th January, 1866): "All sorts of marine vegetation of Upper Silurian and Devonian ages seem there in great abundance, and petroleum everywhere in the Devonian, and oozing from the lower Helderberg limestone formation."

Still deeper the Lower Silurian has small deposits of bitumen in cavities of limestone, even when every trace of organism has disappeared. This fact again is, I think, another indication of the relation of petroleum to a marine vegetation. For it is well understood that vegetable life has ruled the seas in its minute representatives, Diatomaceæ, Desmidiaceæ, long before animal life could be supplied or sustained by it. These diminutive and primitive oil reservoirs are attributable to the concentration and decomposition of a local surplus of that primordial vegetation.

The geographical distribution of petroleum and that of the remains of marine Algæ present the same remarkable coincidence. At Oil Creek, Slippery Rock Creek, in the Chemung of Virginia, Ohio, Kentucky, everywhere indeed where oil has been seen, either in cavities or saturating the rocks, and where the strata were open to view, a remarkable amount of Fucoidal remains has been observed. This cannot be a mere casual coincidence.

The discussion presented in the last part of this paper may then be closed by this assertion: That though the theory of the origin of petroleum from marine vegetables is not yet supported by direct experiments and conclusive proofs, the reasons in favor of it are weighty enough to merit due consideration. The more so, that if recognized true, the theory presents an important chapter of the history of petroleum, and may prove of great value in its application.

Les Lesquereux, del.

T. Sinclair's lith, Phil^a